

**DEVELOPING NEW CHEMICAL-RHEOLOGICAL
MODELS AND CHEMICAL-DURABILITY INDICES OF
BITUMEN**

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DEDICATION

I dedicate this work to my beloved parents:

Mr. Ambia Robandi Padliwinata & Mrs. Deetje Helena Tiodora Paulana (alm)

Also to my beloved wife and children:

- Ika Rostika
- Zikri Rachman
- Fikri Fauzi Rahman
- Ziyen Adilah Rahmah
- Zahra Farida Rahmah

To my youngest brother who has supported me:

- Mr. Yadi Hermayadi

To my superior who I respect:

- Ir. Irman Nurdin (alm)
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PTTA
PERPUSTAKAAN TUNKU AMINAH

ABSTRACT

Significant correlation among chemical properties, rheological characteristics and durability of bitumen is very important in evaluating and modifying bitumen. However, a number of previous studies found inconsistent correlation. Therefore, a study on developing new chemical-rheological models and chemical-durability indices was carried out. Two bitumen fractionation method, Rostler and Corbett methods were used to extract each chemical fraction of bitumen. A number of experiments were conducted to evaluate the effect of each chemical fraction on bitumen rheology such as the effect of asphaltenes, polar aromatics, naphthene aromatics, nitrogen bases, first acidaffins, second acidaffins and paraffins on elastic modulus (G'), viscous modulus (G'') or fatigue factor ($G^*\sin[\delta]$), and rutting factor ($G^*/\sin[\delta]$). Two bitumen from different sources, namely Petronas petroleum bitumen and Buton rock asphalt (BRA) bitumen, were used. New chemical-rheological models were formulated to estimate the bitumen rheology in incorporating parameters which are G' , G'' or ($G^*\sin[\delta]$), and ($G^*/\sin[\delta]$) based on the chemical properties. Furthermore, new chemical durability indices that may indicate the ageing rate of bitumen during short-term and long-term ageing were also formulated. Based on statistical analyses, the models and the indices, which were developed by using chemical properties according to Rostler method were found to be invalid because the real and the predicted rheology were significantly different. While according to Corbett method the models and the indices were valid because the differences is not significant since t-score of the models and the indices were maximum 2.679 and 2.119 or less than t-critical 2.797 and 2.861 respectively). The novelties of this study are the new models and the new indices can be used to predict the bitumen rheology and ageing rate based on the chemical composition. Furthermore, they are very important as guides in modifying a bitumen chemical composition to produce a bitumen mixture with the desired rheology and short-term or long-term ageing rate.

ABSTRAK

Korelasi yang signifikan antara sifat kimia, ciri reologi dan ketahanan bitumen adalah sangat penting dalam menilai dan mengubahsuai bitumen. Walau bagaimanapun, beberapa kajian sebelum ini mendapati bahawa korelasi ini adalah tidak konsisten. Oleh itu, satu kajian mengenai pembangunan model baru reologi-kimia dan indeks ketahanan-kimia bitumen telah dijalankan. Dua kaedah pemeringkatan bitumen, iaitu kaedah Rostler dan Corbett telah digunakan untuk mengekstrak setiap bahagian kimia bitumen. Beberapa percubaan telah dijalankan untuk menilai kesan setiap bahagian kimia terhadap reologi bitumen seperti kesan *asphaltenes*, *polar aromatics*, *naphthene aromatics*, *nitrogen bases*, *first acidaffins*, *second acidaffins* dan *paraffins* kepada modulus elastik (G'), modulus kelikatan (G''), factor ubah bentuk ($G' \sin[\delta]$) dan factor aliran ($G''/\sin[\delta]$). Dua bitumen dari sumber yang berbeza, iaitu bitumen petroleum Petronas dan asphalt batu Buton (BRA), telah digunakan. Model baru reologi-kimia telah dirangka untuk menganggar ciri-ciri reologi bitumen, seperti G' , G'' atau $G' \sin[\delta]$, dan $G''/\sin[\delta]$ berdasarkan sifat kimia. Di samping itu, indeks ketahanan kimia baru yang menunjukkan kadar penuaan bitumen semasa jangka pendek dan jangka panjang penuaan juga telah dirangka. Berdasarkan analisis statistik, model dan indeks yang dibangunkan dengan menggunakan sifat-sifat kimia mengikut Rostler tidak sah kerana reologi sebenar dan yang diramalkan berbeza secara ketara. Manakala menurut kaedah Corbett, model dan indeks tersebut adalah sah kerana perbezaan sebenar dan yang diramalkan tidak ketara atau t-skor model dan indeks adalah maksimum 2,679 dan 2,119 atau kurang dari pada masing-masing t-kritikal 2,797 dan 2,861. Penemuan ini merangkumi model dan indeks baru yang boleh digunakan untuk meramalreologi dan indeks ketahanan bitumen berdasarkan ciri-ciri kimia. Tambahan pula, penemuan ini juga adalah sebagai panduan dalam mengubahsuai bitumen untuk menghasilkan campuran dengan ciri-ciri reologi dan kadar penuaan jangka pendek atau jangka panjang yang dikehendaki..

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LIST OF SYMBOLS AND ABBREVIATIONS

A	Asphaltenes
A ₁	First acidaffins
A ₂	Second acidaffins
AI	Ageing Index
BBR	Bending Beam Rheometer
BRA	Buton Rock Asphalt, that natural rock asphalt from Buton Island
CDI	Chemical Durability Index
CDI-I	Chemical Durability Index based on Rostler fractionation method
CDI-II	Chemical Durability Index based on Corbett fractionation method
cP	Centi Poises
CSS	Creep Strain Slope
DSR	Dynamic Shear Rheometer
DTT	Direct Tension Test
ESALs	Equivalent single axle loads
δ	phase angle
FID	Fame Ionization Detection
FTIR	Fourier Transforms Infrared Spectroscopy
G'	Elastic modulus
G''	Viscous modulus
G*	Complex shear modulus
$G^*/\sin[\delta]$	Rutting factor to indicate rutting susceptibility
$G^*\sin[\delta]$	Fatigue factor to indicate fatigue susceptibility
G _{mm}	Maximum specific gravity
GR	Gotolski Ratio

H_2SO_4	Sulfuric acid
85% H_2SO_4	Glover sulfuric acid
98% H_2SO_4	Concentrated sulfuric acid
$\text{H}_2\text{SO}_4 + \text{SO}_3$	Fuming sulfuric acid
$\text{H}_2\text{S}_2\text{O}_7$	Fuming sulfuric acid
HP-GPC	High Performance Gel Permeation Chromato-graphy
HMA	Hot mix asphalt
HMAC	Hot mix asphalt concrete
Hz	Hertz
I.E.C.	Ion Exchange Chromatography
I_A	Asphalten Index
I_G	Gastel Index
I_C	Colloidal Index
IDT	Indirect tension
ITFT	Indirect Tensile Fatigue Test
ITSM	Indirect tensile stiffness modulus
Kabungka BRA	Buton Rock Asphalt from Kabungka region
kPa	Kilo Pascals
Lawele BRA	Buton Rock Asphalt from Lawele region
Long-term ageing	Ageing of bitumen during asphalt pavement construction and in service
MP	Melting point
N	Nitrogen bases
N_i	Gyrations numbers at initial compaction
N_d	Gyrations numbers at design compaction
N_{\max}	Gyrations numbers at maximum compaction
OBC	Optimum bitumen content
P	Paraffins
Pa·S	Pascal Second
PAV	Pressure Ageing Vessel that used to simulate long-term ageing condition of bitumen
PAV-aged	After long-term ageing that simulated by PAV
PG	Performance Grade

POBC	Predicted optimum bitumen content
RDR	Rostler Durability Ratio
RTFOT	Rolling Thin Film Oven Test that used to simulate short-term ageing condition of bitumen
RTFOT-aged	After short-term ageing that simulated by RTFOT
RV	Rotational Viscometer
SARA	Saturates, Aromatics, Resin and Asphaltene
SGC	Superpave Gyratory Compactor
Short-term ageing	Ageing of bitumen during construction of asphalt pavement
SHRP	Strategic Highway Research Program
T	Maximum applied torque,
TFOT	Thin Film Oven Test that used to simulate short-term ageing condition of bitumen
T _g	Glass transition temperature
TLC	Thin Layer Chromatography
TSR	Tensile strength ratio
UTM	Universal Testing Machine
UV	Ultraviolet rays or electromagnetic radiation with a wavelength shorter than that of visible light, but longer than X-rays
VMA	Voids in Mineral Aggregate
W _c	Work dissipated per load cycle,
τ	shear stress
γ	shear strain response
τ_{\max}	Maximum applied shear stress
γ_{\max}	Maximum response shear strain
σ_o	Applied stress
ϵ_o	Strain
R	Radius of specimen
θ	Deflection (rotation) angle
H	Height of specimen
S(t)	Creep stiffness at the time

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